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SOME FACTORS AFFECTING SURVIVAL, GROWTH, AND SELECTION OF LAMBS

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CONTENTS

INTRODUCTION

Selection based on visual observation and personal judgment has played a large part in both practical and experimental livestock breeding since the beginning of livestock improvement. This method still remains the principal tool with which experimenters in this field evaluate their animals. Without doubt the trained observer can detect differences among animals with considerable accuracy. However, the question arises as to whether the breeder or experimenter allows the effects of nongenetic factors to bias his judgment in selecting animals, thereby reducing his chances of choosing the genetically superior animals for breeding purposes.

Progress in experimental breeding of livestock has lagged behind that of small animals because of certain difficulties not generally encountered in experiments with laboratory animals. The relative slowness in reproduction and the initial value and cost of maintenance of animals such as cattle, horses, sheep, and swine, are two of the chief obstacles. Because of the inevitably greater time and expense required for experiments with these animals, environmental factors also present obstacles. Accordingly, it is important that attention be given to the effects of such nongenetic factors, either by standardizing environmental conditions or by making proper allowance and correction for the effects of such factors in interpreting experimental results, or both.

One method of approaching this problem is to determine whether selection as now practiced is affected by known factors that are nongenetic in nature.

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It is generally recognized that during its early postnatal development the single lamb will be heavier than the lamb born in a multiple birth. The twin or triplet is hampered by having to share both uterine nutrients and space, and also the milk supply of its dam after birth. Therefore, at an age before this initial handicap can be overcome, the twin appears at a disadvantage when compared with the single lamb.

Lambs born late in the lambing season also would be expected to appear at a disadvantage when compared with older lambs on the same date. In addition to the younger age, a handicap to the later lamb may be exposure, at an earlier stage in development, to the disadvantages which usually accompany hot summer weather.

Birth weight, if correlated with weight at the time of selection, would also be expected to have an effect on selection. A positive relationship between weight at birth and subsequent weights has been shown to exist in swine by Cole and Kuhlman, according to Clark (*4*),[2] Lush, Culbertson, and Hammond (*7*), and Russell;[3] in cattle by Kusner (*6*) and the Arizona Agricultural Experiment Station (*1*); and in sheep by Phillips (*10*, *11*) and Schneider and Hundt as quoted by Kliesch (*5*).

The question of the extent to which these factors are environmental or genetic in nature will immediately arise in the mind of the reader. Whether a ewe will produce single or multiple lambs is apparently determined to some extent by genetic factors. Literature on this point is reviewed by Roberts and Crew (*12*) and Kliesch (*5*). The determination of time of birth may be partly controlled by genetic factors, insofar as the time of onset of oestrus is concerned. Birth weight is apparently determined by both genetic and environmental factors. Chapman and Lush (*3*) have shown that approximately 25 to 30 percent of the variance in the birth weights of lambs can be accounted for by genetic differences, 30 to 35 percent by tangible environment, and 40 to 45 percent by intangible environment or accidents of development. Sex is controlled by genetic factors, of course. Again, with reference to single and multiple births, two lambs, one a single and one a twin, may have the same potentialities for development of mutton form. The fact that they differ in type of birth may be due in part to genetic factors, but the influence of type of birth may enable the single lamb to develop more rapidly than the twin, and so far as mutton development at the time of selection is concerned type of birth, whether single or multiple, is an environmental effect in favor of the single lamb. From this standpoint, time of birth, birth weight, and sex also behave as environmental factors. If comparisons are to be made between lambs or groups of lambs differing in these factors, adjustments must be made for their effects. Since approximately 30 percent of the weight at birth is attributable to genetic influences, adjustment would be made in this case for only 70 percent of the differences in later weights associated with differences in birth weight.

If the factors mentioned can be demonstrated to have definite effects on selection, even though they may have only minor effects on development as compared with those of differences in season and feeding and management practices, the time is certainly ripe for a thorough study

[2] Italic numbers in parentheses refer to Literature Cited, p. 16.

[3] RUSSELL, E. Z. THE RELATION OF BIRTH WEIGHT TO GROWTH IN PIGS. Ext. Anim. Husbandman, Serial No. 27. 1932. [Mimeographed.]

of their effects on the selection of breeding animals and of the extent to which they influence the evaluation of breeding experiments.

The primary objects of these studies were to show (1) whether the effects of birth factors (type of birth, time of birth, and birth weight) lessened the efficiency of the method of selection used and (2) whether any differences found could be accounted for by the effects of these birth factors on survival and growth.

MATERIAL AND METHODS

The data used in this study were obtained on lambs born during a 14-year period (1921–34) in the flock at the Department's Animal Husbandry Experiment Station, Beltsville, Md. This flock has been maintained for use in experimental breeding, feeding, and management studies. A constant effort has been made to improve the merit of the individual animals and the uniformity of the flock. The management has included the use of temporary and permanent pastures in the summer and barn feeding during the winter months. The breeding animals have been kept in good condition but not excessively fat. The lambs have been creep-fed during the suckling period and weaned about August 1.

The flock has also been used in other experiments, such as the determination of the effects of flushing on the occurrence of multiple births (*8*) and studies of the extent to which temporary pastures may be advantageously used (*9*). Such experiments resulted in some variation in the kinds of feed and feed levels used, but in general all animals received adequate nutrients, and it is believed that these variations in feed and management were not of such character as to affect the value of results presented herein.

During the period of this study 508 Hampshire, 521 Shropshire, and 835 Southdown lambs were born for which data were available. The numbers of lambs, grouped according to breed, sex, and type of birth, are given in table 1.

TABLE 1.—*Numbers of lambs born, grouped according to breed, sex, and type of birth, and the average birth weights in each group in the flock studied*

Breed	Sex	Lambs born—					Average birth weights [1] of—			
		As singles	As twins	As triplets	As quadruplets	Total	Singles	Twins	Triplets	Quadruplets
		Number	*Number*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Hampshire	Male	111	142	12	2	267	11.3	9.5	7.8	7.2
	Female	110	[2] 117	12	2	241	10.6	8.7	7.3	6.0
Shropshire	Male	119	142	7	0	268	9.7	7.8	6.5	----
	Female	111	140	2	0	253	9.0	7.7	5.8	----
Southdown	Male	229	230	2	0	461	8.5	7.0	5.9	----
	Female	194	176	4	0	374	8.0	6.5	3.9	----

[1] Recorded to nearest 0.1 pound at or near time of birth.
[2] One twin omitted; born dead and data on sex and weight not obtained, hence the uneven number of twins.

The taking of data on type of birth, date of birth, birth weight, and sex was a routine procedure; hence, data were available on all these points. The number of triplets born was small, and there was only one set of quadruplets in a total of 1,362 births; consequently, only singles and twins were considered in the analysis. The relative time in the

lambing season in which each lamb was born was determined as follows: The date on which the first lamb was born in each season was considered as zero, and the number of days after that on which each lamb was born was used to indicate the relative time of birth. Birth weights were recorded to the nearest 0.1 pound as soon after birth as possible and never later than 24 hours. Weights of all lambs in the flock were then taken to the nearest pound once weekly up to 1 year of age.

In selecting animals for breeding purposes, those that appeared to be superior in mutton form, growth rate, fleece, and breed type were retained. Emphasis was placed primarily on mutton form. The proportions of the various groups that were retained to 12 months of age were used as measures of suitability for breeding. The lambing season usually extended from late in January to early in May, most of the lambs being born in February and March. The first culling was done about August 15, the definitely undesirable lambs being eliminated and the remainder being retained for further observation. The next culling occurred about November 15, when only those lambs that were considered sufficiently good for use in the breeding flock were retained. No further culling was done until after the animals were 1 year of age, when any in excess of replacement requirements were eliminated. In the selection process all animals were evaluated by a well-trained sheep husbandman.

The proportions in the various groups that were alive at 3 months of age were used as measures of survival of the lambs. As already indicated, culling was done before this age. Some deaths were undoubtedly due to disease or accident not associated with low vitality. However, it seems reasonable to assume that these occurred at random in the various groups and that the numbers are sufficiently large to eliminate any material differences due to these causes; hence, the proportion of any group remaining alive at 3 months of age should give a fairly accurate measure of vitality.

The weights at 3, 6, and 12 months were used as measures of the relative growth of lambs in the various groups. Since weights were taken once weekly, weights within 3 days of the ages given were available.

The studies of the relations of birth factors to weight were based on data on all the lambs remaining in the flock to the ages of 3, 6, and 12 months. However, only the 3-month-old group was not affected by eliminations from other than natural causes and may thus be considered as an unselected sample. The studies dealing with the weights taken at both 6 and 12 months, especially the latter, were made on animals affected by selection. This weakness of the data from the standpoint of determining the effects of birth factors on weights at 6 and 12 months was unavoidable because a number of the lambs were eliminated by culling before 6 months of age, and a still larger number before 12 months. The probable results, had the whole population been retained, are a matter of conjecture, but it seems reasonable to believe that selection reduced the variability of the population and that differences at 6 and 12 months would have been larger had the entire population been available for study.

The statistical techniques used in studying the various problems are included in the discussion of the experimental results. In all cases probability (p) values were used to indicate the statistical sig-

nificance of results. The arbitrary levels of these values are as follows: 0.01 or less, highly significant; 0.05 to 0.01, significant; more than 0.05, not significant. All values less than 0.01 are indicated as <0.01.

EXPERIMENTAL RESULTS

RELATION OF BIRTH FACTORS TO SELECTION OF BREEDING ANIMALS

To study the relation of birth factors to the apparent suitability of the animals for breeding, the lambs in each breed and sex group that were retained to 12 months of age were classified in three ways: Single and twin lambs, early and late lambs, and heavy and light lambs. In the last two classifications the lambs in each group were arbitrarily divided at the median point of their respective distributions. A summary of data obtained on the three classifications is presented in table 2.

TABLE 2.—*Relation of birth factors to suitability of animals for breeding, as judged by the selection method used, expressed as percentages of lambs born that were retained to 12 months of age*

Sex	Groups compared	Hampshire			Shropshire			Southdown		
		Lambs retained	Difference	Significance of difference (p values)	Lambs retained	Difference	Significance of difference (p values)	Lambs retained	Difference	Significance of difference (p values)
		Percent	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*	
TYPE OF BIRTH										
Male	Single	45.0	10.2	0.10	46.6	27.6	<0.01	36.44	8.64	0.06
	Twin	34.8			19.0			27.80		
Female	Single	63.0	13.9	.06	44.9	1.4	.83	59.07	10.53	.06
	Twin	49.1			46.3			48.54		
TIME OF BIRTH										
Male	Early	48.8	19.2	<0.01	38.8	14.8	0.01	40.62	16.96	<0.01
	Late	29.6			24.0			23.66		
Female	Early	65.8	19.9	<.01	50.8	10.2	.15	65.38	22.52	<.01
	Late	45.9			40.6			42.86		
BIRTH WEIGHT										
Male	Heavy	47.2	16.0	<0.01	45.0	27.2	<0.01	41.52	18.75	<0.01
	Light	31.2			17.8			22.77		
Female	Heavy	69.4	27.1	<.01	52.6	15.9	.02	62.09	15.94	<.01
	Light	42.3			37.7			46.15		

The significance of differences in the proportion of each group retained to 12 months of age was determined by the use of the χ-square test in 2-by-2 tables, use being made of the numbers of individuals in the respective classes for which percentages are given in table 2. The data were tested for triple interactions by the method of Barlett (*2*). Significant interactions between any two of the birth factors and selection were found only between type of birth, birth weight, and selection in the Hampshire females ($p=0.03$).

In five of the six groups compared, a higher proportion of single than of twin lambs was retained. In one group this difference was highly significant, and in three it was on the border line of significance

($p=0.06$). A tendency to select single lambs more often than twins therefore seems apparent.

Early lambs were favored over late ones in all six groups compared, the differences in favor of the early lambs being highly significant in five cases.

The lambs that were heavier at birth were also favored in the selection of breeding stock since a higher proportion of the heavy lambs than of the light lambs was retained to 12 months of age. Of the six groups in which comparisons were made, the differences in favor of heavy lambs were significant in one case and highly significant in the remainder.

As is shown later (table 4) the ability of lambs to survive to 3 months of age is related to time of birth and birth weight. Therefore, the data dealing with selection were reexamined to determine whether any effects of birth factors could be demonstrated when the study was based on the proportion of lambs alive at 3 months of age in each group that were retained to 12 months of age rather than on the proportion of lambs born that were retained to that age. A summary of these data is presented in table 3. The method of classifying and analyzing the data was the same as in the studies of selection and survival reported in table 2.

TABLE 3.—*Relation of birth factors to suitability of animals for breeding, as judged by the method of selection used, expressed as percentages of lambs surviving to 3 months of age that were retained to 12 months of age*

Sex	Groups compared	Hampshire			Shropshire			Southdown		
		Lambs retained	Difference	Significance of difference (p values)	Lambs retained	Difference	Significance of difference (p values)	Lambs retained	Difference	Significance of difference (p values)
TYPE OF BIRTH		*Percent*	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*	
Male	Single	53.8	11.9	<0.01	56.3	32.8	<0.01	46.1	11.5	0.03
	Twin	41.9			23.5			34.6		
Female	Single	73.1	10.9	.12	55.1	.8	.92	70.8	13.9	.01
	Twin	62.2			54.3			56.9		
TIME OF BIRTH										
Male	Early	56.0	18.6	0.01	46.3	16.2	0.02	47.1	15.0	<0.01
	Late	37.4			30.1			32.1		
Female	Early	74.5	14.5	.04	60.8	12.3	.09	76.8	25.5	<.01
	Late	60.0			48.5			51.3		
BIRTH WEIGHT										
Male	Heavy	53.6	13.8	0.07	51.8	28.6	<0.01	47.9	16.6	<0.01
	Light	39.8			23.2			31.3		
Female	Heavy	77.8	21.8	<.01	60.6	12.7	.11	71.5	15.1	<.01
	Light	56.0			47.9			56.4		

The comparison of single and twin lambs shows that a higher proportion of the singles was retained in each of the six groups. The differences were significant or highly significant in all the ram groups and in the Southdown ewe group, but there was not definite evidence of discrimination against twins in the Hampshire and Shropshire ewe groups.

In all cases a higher percentage of the early lambs was retained, the differences between the early and late groups being significant or highly significant in five of the six cases. A higher proportion of heavy than of light lambs was also retained in all cases, the differences being highly significant in four of the six cases. These data show a definite tendency to favor lambs that are born early and that are heavy at birth.

From these results it is evident that lambs born as singles or early in the season or that were heavy at birth tended to be favored in selection. From a genetic standpoint this result reduces the chances of selecting animals that are superior in mutton form, since there is no apparent reason to assume that any one of these groups should have more desirable genes for mutton qualities than any other group. The favoring of singles might also be interpreted as selection against the trait of twinning. This is not necessarily so, however, since if only half as large a proportion of twins as of singles is retained, dams producing those single and twin lambs will be represented equally in the offspring retained for breeding.

RELATION OF BIRTH FACTORS AND SEX TO SURVIVAL

Data showing the relation of birth factors and sex to survival are summarized in table 4. The material was classified and analyzed in the same manner as that in the study of the relation of birth factors to suitability for breeding. No significant interactions were found between any two of the birth factors and ability to survive.

TABLE 4.—*Relation of type and time of birth, birth weight, and sex to survival of lambs to 3 months of age*

Sex	Groups compared	Hampshire			Shropshire			Southdown		
		Lambs surviving	Difference	Significance of difference (p values)	Lambs surviving	Difference	Significance of difference (p values)	Lambs surviving	Difference	Significance of difference (p values)
TYPE OF BIRTH		*Percent*	*Percent*		*Percent*	*Percent*		*Percent*	*Percent*	
Male	Single	83.5	0.5	0.93	82.8	1.8	0.73	79.1	1.2	0.76
	Twin	83.0			81.0			80.3		
Female	Single	86.1	7.2	.18	81.6	3.6	.40	83.4	2.0	.60
	Twin	78.9			85.2			85.4		
TIME OF BIRTH										
Male	Early	87.2	8.0	0.09	83.7	3.9	0.65	85.7	12.0	<0.01
	Late	79.2			79.8			73.7		
Female	Early	88.3	11.7	.03	83.6	.1	.92	85.2	1.7	.40
	Late	76.6			83.7			83.5		
BIRTH WEIGHT										
Male	Heavy	88.0	9.6	0.04	86.8	10.1	0.03	86.6	13.8	<0.01
	Light	78.4			76.7			72.8		
Female	Heavy	89.2	13.5	<.01	88.5	9.9	.04	86.8	4.9	.18
	Light	75.7			78.6			81.9		
SEX										
Male	Single	83.5	2.6	0.75	82.8	1.2	0.95	79.1	4.3	0.30
Female	Single	86.1			81.6			83.4		
Male	Twin	83.0	4.1	.50	81.0	4.2	40	80.3	5.1	.20
Female	Twin	78.9			85.2			85.4		

No consistent differences were found in the ability of single and twin lambs to survive to 3 months of age. None of the differences were large enough to be considered significant, and of the differences that were found three favored the single and three the twin lambs.

The data in table 4 dealing with time of birth give some indication of a tendency for more of the early lambs to survive. In one group the difference in favor of early lambs is highly significant, in another it is significant, and in three of the four remaining groups the differences are not so marked but are in the same direction. This tendency for more of the early lambs to survive may be due to the fact that late lambs were exposed to hot weather and to possible infestation with intestinal parasites at an earlier stage in their development.

The data in table 4 dealing with birth weight show a definite tendency for more of the heavy lambs at birth to survive. In all cases more of the heavy than of the light lambs survived to 3 months of age, and in five cases the differences in favor of the heavy lambs were significant or highly significant. A similar relationship between birth weight and survival was indicated in preliminary studies in lambs by Phillips (*10*, *11*), and in swine by Russell [4] and Cole and Kuhlman, according to Clark (*4*).

Since the data were biologically divided into singles and twins and since no significant differences were found between them, comparisons between males and females were made only within each of these two divisions. These data, presented in table 4, have no bearing on the problem of selection but are included here because of their general interest. In neither the single nor twin groups of any breed were significant differences found between the two sexes in ability to survive.

RELATION OF BIRTH FACTORS AND SEX TO GROWTH

If the birth factors have an effect on development, it seems obvious that this would account for at least a part of the relation of these factors to the selection of breeding animals. Hence, a study was made of the relation of these birth factors to growth as measured by body weight at 3, 6, and 12 months of age. The data were analyzed by the method of multiple regression and covariance described by Snedecor (*13*).

A summary of results obtained is given in table 5. Single lambs were heavier than twin lambs at 3 months of age, the differences in favor of the singles being highly significant in the six groups studied. The differences remained significant after adjusting by linear regression for the effects of birth weight and for the effects of both birth weight and date of birth. This finding indicates that a significant part of the difference in the weights of single and twin lambs at 3 months cannot be accounted for by association between type of birth and birth weight or time of birth.

[4] See footnote 3, p. 2.

TABLE 5.—*Relation of type of birth of lambs to weights at 3, 6, and 12 months of age*

Breed	Sex	Type of birth	Weights at 3 months					Weights at 6 months							Weights at 12 months						
			Mean weight	Difference	Significance of differences (p values)			Mean weight	Difference	Significance of differences (p values)					Mean weight	Difference	Significance of differences (p values)				
					Unadjusted	Adjusted for—				Unadjusted	Adjusted for—						Unadjusted	Adjusted for—			
						Birth weight	Birth weight and time of birth				Birth weight	Date of birth	Weight at 3 months	All three factors				Birth weight	Date of birth	Weight at 3 months	All three factors
			Lb.	*Lb.*				*Lb.*	*Lb.*						*Lb.*	*Lb.*					
Hampshire	Male	Single	67.4	10.0	<0.01	<0.01	<0.01	95.9	7.5	<0.01	0.45	<0.01	0.10	0.06	150.3	5.3	[1]0.17	------	------	------	------
		Twin	57.4					88.4							145.0						
	Female	Single	60.5	8.4	<.01	.03	<.01	84 8	6.8	<.01	.60	<.01	.06	.14	130.3	5.9	.04	0.10	0.01	0.03	0.15
		Twin	52.1					78.0							124.4						
Shropshire	Male	Single	55.5	10.5	<.01	.01	<.01	77.4	6.9	<.01	.66	<.01	.49	.18	127.4	5.8	[1].14	------	------	------	------
		Twin	45.0					70.5							121.6						
	Female	Single	50.4	6.2	<.01	<.01	<.01	69.5	5.0	<.01	.17	<.01	.12	.28	109.6	3.9	[1].23	------	------	------	------
		Twin	44.2					64.5							105.7						
Southdown	Male	Single	49.0	7.5	<.01	<.01	<.01	71.8	6.0	<.01	.99	<.01	.18	.99	109.2	3.2	[1].12	------	------	------	------
		Twin	41.5					65.8							106.0						
	Female	Single	45.0	7.0	<.01	<.01	<.01	63.3	6.2	<.01	.46	<.01	.52	.29	99.6	8.6	<.01	<.01	<.01	.03	.03
		Twin	38.0					57.1							91.0						

[1] No adjustments were made since unadjusted differences were not significant.

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Since single lambs were heavier than twins at 3 months of age, it is of interest to ascertain whether a difference exists at birth or develops thereafter. A study of the differences between single and twin lambs within each of the breed and sex groups for which mean weights are given in table 1 showed that in every case singles were significantly heavier at birth ($p = < 0.01$).

The single lambs were likewise heavier than twins at 6 months of age, as shown also in table 5, the differences being highly significant in all groups. When these weights were adjusted by linear regression for differences in birth weight or weight at 3 months, it was shown that there was not a significant difference between the weights of single and twin lambs except as it was associated with these two factors. Differences in weights were still highly significant after adjusting for differences in date of birth.

Single lambs were also heavier than twins in all groups at 12 months, but the differences were significant and highly significant, respectively, in only two groups, the Hampshire females and the Southdown females.

In general, there was a tendency for differences in weight due to type of birth to disappear as the animals matured.

As shown in table 6, the relative time in the lambing season at which a lamb was born also had an effect on the weight at 3 months of age. The regression coefficients, which show the difference in weight for each day's difference in time of birth, all indicate that later lambs weighed less than earlier lambs at 3 months. These regression coefficients were significant or highly significant in 10 of the 12 groups.

TABLE 6.—*Relation of time of birth to growth of lambs, as shown by regression coefficients*

Breed	Sex	Type of birth	Regression coefficients,[1] with standard error					
			At 3 months	Significance (p values)	At 6 months	Significance (p values)	At 12 months	Significance (p values)
			Pounds		*Pounds*		*Pounds*	
Hampshire	Male	Single	−0.11±0.05	0.05	−0.14±0.07	0.06	+0.13±0.10	0.20
		Twin	−.14± .04	<.01	+.004± .07	.90	+.26± .18	.15
	Female	Single	−.17± .05	<.01	−.15± .06	<.01	−.21± .09	.02
		Twin	−.15± .04	<.01	+.09± .06	.15	−.14± .09	.65
Shropshire	Male	Single	−.14± .04	<.01	−.12± .06	.05	+.28± .11	.02
		Twin	−.09± .04	.04	−.01± .01	.90	−.03± .13	.80
	Female	Single	−.09± .04	.04	−.18± .05	<.01	+.01± .27	.90
		Twin	−.02± .04	.62	+.003± .05	.90	+.02± .13	.85
Southdown	Male	Single	−.14± .03	<.01	−.08± .04	.05	+.12± .07	.08
		Twin	−.04± .04	.31	−.15± .06	<.01	+.05± .12	.71
	Female	Single	−.08± .03	<.01	−.09± .03	<.01	−.10± .05	.08
		Twin	−.11± .04	<.01	−.19± .04	<.01	−.21± .08	.01

[1] Average difference in weight for each day's difference in time of birth.

Data showing the relation of time of birth to weights at 6 and 12 months indicate that the effect of time of birth tends to disappear as the animals mature. Seven of the regression coefficients were significant or highly significant at 6 months and only 3 at 12 months, as

compared with 10 at 3 months. All the regression coefficients were negative at 3 months, whereas at 6 months 3 were positive and 9 were negative, and at 12 months 7 were positive and 5 were negative.

The effect of birth weight is similar to that of type and time of birth in that it has a definite relationship with weight at 3 months and a less marked effect at later ages. Data on this point are presented in table 7. The regression coefficients indicate the differences in weight at 3, 6, and 12 months which are associated with each difference of 1 pound in birth weight. A positive relationship was found in all cases between birth weight and weight at 3 months, and all the regression coefficients were highly significant. At 6 months only 3 of the regression coefficients were significant or highly significant, and 3 of the remaining 9 were negative. At 12 months only 1 regression coefficient was significant and 4 of the remaining 11 were negative.

TABLE 7.—*Relation of birth weight to growth of lambs, as shown by regression coefficients*

Breed	Sex	Type of birth	Regression coefficients,[1] with standard error					
			At 3 months	Significance (*p* values)	At 6 months	Significance (*p* values)	At 12 months	Significance (*p* values)
			Pounds		*Pounds*		*Pounds*	
Hampshire	Male	Single	+2.66 ±0.56	<0.01	+0.38 ±0.77	0.63	+2.00 ±1.17	0.09
		Twin	+2.86 ± .48	< .01	+1.78 ± .85	.05	+2.21 ±2.37	.35
	Female	Single	+2.36 ± .55	< .01	+ .70 ± .63	.27	−2.75 ±1.61	.09
		Twin	+2.35 ± .47	< .01	+ .23 ± .66	.75	− .24 ±1.07	.85
Shropshire	Male	Single	+3.23 ± .57	< .01	+2.46 ± .88	<.01	+4.97 ±1.86	.01
		Twin	+2.78 ± .53	< .01	+1.35 ±1.10	.23	+2.60 ±1.84	.18
	Female	Single	+2.16 ± .65	< .01	− .64 ± .62	.31	− .76 ±1.60	.70
		Twin	+3.09 ± .49	< .01	− .53 ± .73	.45	+2.43 ±1.67	.15
Southdown	Male	Single	+4.27 ± .57	< .01	+ .66 ± .73	.37	+ .78 ±1.50	.60
		Twin	+2.10 ± .50	< .01	− .71 ± .74	.35	+ .14 ±1.49	.90
	Female	Single	+2.20 ± .40	< .01	+1.46 ± .42	<.01	+ .82 ± .89	.36
		Twin	+1.65 ± .52	< .01	+ .12 ± .60	.85	− .11 ±1.11	.90

[1] Regression coefficients indicate average difference in weight for each pound of difference in birth weight

The effect of sex on weights at 3, 6, and 12 months of age apparently differs from the effects of the three factors already discussed in that the difference between the sexes becomes more pronounced as the animals mature. The data in table 1 show that males were heavier than females at birth in all groups. These differences between males and females were highly significant ($p=<0.01$) in all groups except the Shropshire twins, for which the difference was not significant. Table 8 shows that this situation still exists at 3 months of age. When adjustments were made for differences in birth weight, the differences remained highly significant in the Hampshire and Southdown single and twin groups but became nonsignificant in the Shropshire single group.

TABLE 8.—*Relation of sex of lambs to weights at 3, 6, and 12 months of age*

Breed	Type of birth	Sex	Weights at 3 months				Weights at 6 months						Weights at 12 months					
			Mean weight	Difference	Significance of differences (p values)		Mean weight	Difference	Significance of differences (p values)				Mean weight	Difference	Significance of differences (p values)			
					Unadjusted	Adjusted for birth weight			Unadjusted	Adjusted for—					Unadjusted	Adjusted for—		
										Birth weight	Weight at 3 months	Birth weight and weight at 3 months				Birth weight	Weight at 3 months	Birth weight and weight at 3 months
			Pounds	*Pounds*			*Pounds*	*Pounds*					*Pounds*	*Pounds*				
Hampshire	Single	Male	67.4	6.9	<0.01	<0.01	95.9	11.1	<0.01	<0.01	0.03	0.03	150.3	20.0	<0.01	<0.01	<0.01	<0.01
		Female	60.5				84.8						130.3					
	Twin	Male	57.4	5.3	<.01	.01	88.4	10.4	<.01	<.01	<.01	.02	145.0	20.6	<.01	<.01	<.01	<.01
		Female	52.1				78.0						124.4					
Shropshire	Single	Male	55.5	5.1	<.01	.09	77.4	7.9	<.01	<.01	<.01	.01	127.4	17.8	<.01	<.01	<.01	<.01
		Female	50.4				69.5						109.6					
	Twin	Male	45.0	.8	[1] .43	-------	70.5	6.0	<.01	<.01	<.01	<.01	121.6	15.9	<.01	<.01	<.01	<.01
		Female	44.2				64.5						105.7					
Southdown	Single	Male	49.0	4.0	<.01	<.01	71.8	8.5	<.01	<.01	<.01	<.01	109.2	9.6	<.01	<.01	<.01	<.01
		Female	45.0				63.3						99.6					
	Twin	Male	41.5	3.5	<.01	<.01	65.8	8.7	<.01	<.01	<.01	<.01	106.0	15.0	<.01	<.01	<.01	<.01
		Female	38.0				57.1						91.0					

[1] No adjustment made since unadjusted difference was not significant.

The differences between males and females were highly significant in all groups at 6 months of age and remained so after adjusting for birth weight and also for weight at 3 months with the exception of the Hampshire single group, for which the significance of the difference was reduced from $p=<0.01$ to $p=0.03$. At 12 months the differences between males and females were highly significant in all groups and remained so after adjusting for birth weight and weight at 3 months, or both.

SEX RATIOS

The numbers of males per 100 females in the Hampshire, Shropshire, and Southdown breeds were 110.8, 105.9, and 123.3, respectively. The sex ratios in the single and twin groups of each breed, based on the figures given in table 1, are presented in table 9. These data were tested to determine whether they differed significantly from a ratio of 50 males to 50 females, and from a 49:51 ratio arrived at by Chapman and Lush (*3*). Both the Southdown single and twin groups differed significantly from the 49:51 ratio, but only the twin group deviated by a significant amount from the 50:50 ratio.

TABLE 9.—*Sex ratios found among the lambs studied and probabilities of significant deviation from expected ratios*

Breed	Type of birth	Males per 100 females	Significance (p values) of deviation from a—	
			50:50 ratio	49:51 ratio
		Number		
Hampshire	Single	100.9	0.90	0.70
	Twin	121.4	.15	.07
Shropshire	Single	107.2	.60	.40
	Twin	101.4	.90	.70
Southdown	Single	118.0	.09	.04
	Twin	130.7	<.01	<.01
Entire group		114.7	<.01	<.01

These sex ratios all show a preponderance of males, and when the data on 1,821 single and twin animals of 3 breeds are combined a ratio of 114.7 males to 100 females is obtained. This is a significant deviation from an equal distribution of the sexes or from the 49:51 ratio obtained by Chapman and Lush (*3*), and it is in the reverse direction of their results.

The tendency toward an excess of males in the Southdown breed and particularly in the twin group led to an investigation of the possibility of occurrence of monozygotic twins in this group. Three sex combinations are possible in twins—both males, one male and one female, and both females. If the numbers of each sex are equal and no monozygotic twinning occurs, the respective numbers in each of these combinations should be in the proportions of 1, 2, and 1. If monozygotic twinning occurs frequently the proportions of combinations of both males, both females, or of both males and females would be expected to increase.

The pairs of Southdown twins on which data on both members were available totaled 195. Of this number 61 were both males, 99 consisted of 1 male and 1 female, and 35 were both females. The

most legitimate test of these proportions seemed to be a comparison with the combinations that would be expected on the basis of the sex ratio of the Southdown single lambs, which was approximately 54 males to 46 females. On this basis the expected proportions would be 57 males, 97 male and female, and 41 females. The deviation from this expected ratio was not significant ($p=0.60$). Hence, it may be assumed that the basic causes for the preponderance of males in the single and twin groups were similar and that a high frequency of monozygotic twinning is not occurring in the male group.

APPLICATION OF RESULTS TO SHEEP BREEDING AND EXPERIMENTATION

The results showed that type of birth, time of birth, and birth weight have influenced the selection of breeding animals. Single lambs have been preferred to twins, early lambs to late ones, and lambs that were heavy at birth to light lambs. With the exception of a portion of the effect of birth weight, the effects of these factors on selection are considered to be environmental in nature, and, therefore, reduce the chances of selecting the genetically superior animals for breeding purposes. This weakness in the present method of selection can be at least partly overcome in one of the following ways:

1. When selections are made at weaning or a similar early age, the animals may be divided, first by sex and then into single and twin groups within sexes. These last two groups should then be divided according to time of birth. If the range in date of birth is 6 weeks, the lambs may be divided into two groups having a range of 3 weeks each. If lambing occurs over a longer period, more groups may be necessary. With the animals so divided, those in each group will be on a more comparable basis than if considered as a whole, and selections can be made within each group. This division does not take into consideration differences in birth weight, and if data on this point are available they may be kept at hand for use while making selections. Selections would, of course, be based on the characters in which the breeder is primarily interested, such as mutton form, fleece, and perhaps other factors such as pedigrees of the animals.

This method eliminates comparison of single lambs with twin lambs and of early lambs with late ones. Assuming that the proportion of individuals possessing superior germ plasm is equal in the groups of singles and twins and that there is a similar porportion in the early and late group in each type of birth, the chances of actually selecting these superior animals would be greater if this suggested system were followed.

2. Selections may be made at a standard age, such as 6 months, rather than on a certain date. Weights at this age could be adjusted for the effects of birth factors, and any advantage or disadvantage kept in mind when evaluating each animal. The weights of all animals could be adjusted to a standard basis, such as single males of a standard birth date and weight, for use in making such allowances for the effects of birth factors and sex. All animals reaching the standard age within a given week might be observed on one day during that week. By this method each individual is compared with an ideal at a standard age, with allowance for any unfavorable environment

due to birth factors. The effect on selection would be similar to that of the first suggested method.

3. Selections might be postponed until an age when the effects of the birth factors on development discussed herein have disappeared. Little effect of type and time of birth and birth weight on development, as measured by weight, remains at 12 months. Retention of all animals to this age is not practical for the sheep breeder who must sell his discarded lambs when they reach market weight, but it may be a worth-while procedure in experimental breeding, unless data taken at younger ages can be shown to be sufficiently representative of the animals' potential development.

Another application of the results of the study presented herein is in the comparing of groups of animals, such as the offspring of two or more rams in progeny testing. If the number of offspring from each of two rams is sufficiently large that practically equal numbers of singles and twins, lambs of heavy and light birth weights, and males and females are available, and if the time of birth of the lambs is comparable, then a comparison of the uncorrected weights of the two groups at a standard age would be valid. However, most young rams are tested on a small number of ewes. If the resulting small number of offspring of a ram are to be compared with those of another ram at an age when the effects of birth factors still persist, the figures given in this circular, or similar figures, can be used in making necessary adjustments. Adjustments for sex can be made in like manner. All animals might be adjusted to a basis of male singles with date of birth and birth weight constant.

SUMMARY AND CONCLUSIONS

The data presented in this circular were taken from the records of the flock at the Animal Husbandry Experiment Station, Beltsville, Md., for the years 1921 to 1934, inclusive. The number of lambs born during this period, upon which data were available, included 508 Hampshires, 521 Shropshires, and 835 Southdowns. Analysis of these data showed the following:

The selection of animals considered to be suitable for breeding was affected by the type and time of birth and birth weight of lambs. Single lambs were preferred to twins, early lambs to late ones, and lambs that were heavy at birth to lighter ones. Since these effects of birth factors are considered to be, for the most part, environmental in nature, their influence on the selection of genetically superior animals is undesirable.

The ability of different groups of lambs to survive to 3 months of age varied somewhat. No consistent difference was found in the survival of singles and twins. There was a tendency for more early than late lambs to survive. A significantly higher proportion of the lambs that were heavy at birth survived than of the light lambs. No significant difference was found in the survival of males and females.

The effects of birth factors on selection could not be explained by differences in the number of lambs surviving to 3 months of age.

Type of birth, time of birth, and birth weight were all related to weights of lambs at 3 months. The weight advantages were in favor of single, early, and heavy lambs, respectively. These effects were

less marked at 6 months and tended to disappear at the age of 12 months. Male lambs were significantly heavier than females at birth in all but one group, and the difference in sexes tended to become more pronounced with increasing age.

The effects of the birth factors on the development of the lambs furnish a logical explanation of the effects of these factors on selection. The animals that developed more rapidly in early life naturally appeared to better advantage; hence single lambs, early lambs, and heavy lambs were favored. Since selections were made at standard times rather than at standard ages, the early lambs had an additional advantage since they were compared with younger lambs.

Suggestions for overcoming the weaknesses of the present selection method are offered. These include the following: Dividing lambs into comparable groups at the time of selection and making comparisons only within these groups, selecting at a standard age rather than a standard date and making due allowance for differences in birth factors, and delaying selection until an age when the effects of birth factors have disappeared. The last method may be applicable only in experimental breeding, and there perhaps only in exceptional cases.

The data on the effects of birth factors and sex on weights at 3, 6, and 12 months, or similar data, may be used to put lambs in small groups on a standard basis so that valid comparisons can be made. This procedure should be useful in the progeny testing of rams.

The high proportions of males in some groups led to an analysis of the sex ratios. A significant preponderance of males was found in the lambs when considered as a whole. The excess of males was most pronounced in the Southdown breed.

The findings in this study indicate an urgent need for thorough study of selection methods as practiced with all classes of livestock and of the use of such findings in improving selection methods and in evaluating the results of breeding experiments, especially in making progeny comparisons.

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